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# Canyon Reservoir
# Comal County, Texas

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

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# U.S. ENVIRONMENTAL PROTECTION AGENCY
# NATIONAL EUTROPHICATION SURVEY

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REPORT

ON

CANYON RESERVOIR

COMAL COUNTY

TEXAS

EPA REGION VI

WORKING PAPER No. 639

WITH THE COOPERATION OF THE

TEXAS WATER QUALITY BOARD

AND THE

TEXAS NATIONAL GUARD

MARCH 1977

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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|---|---|---|
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# FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

## OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

## ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

## LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

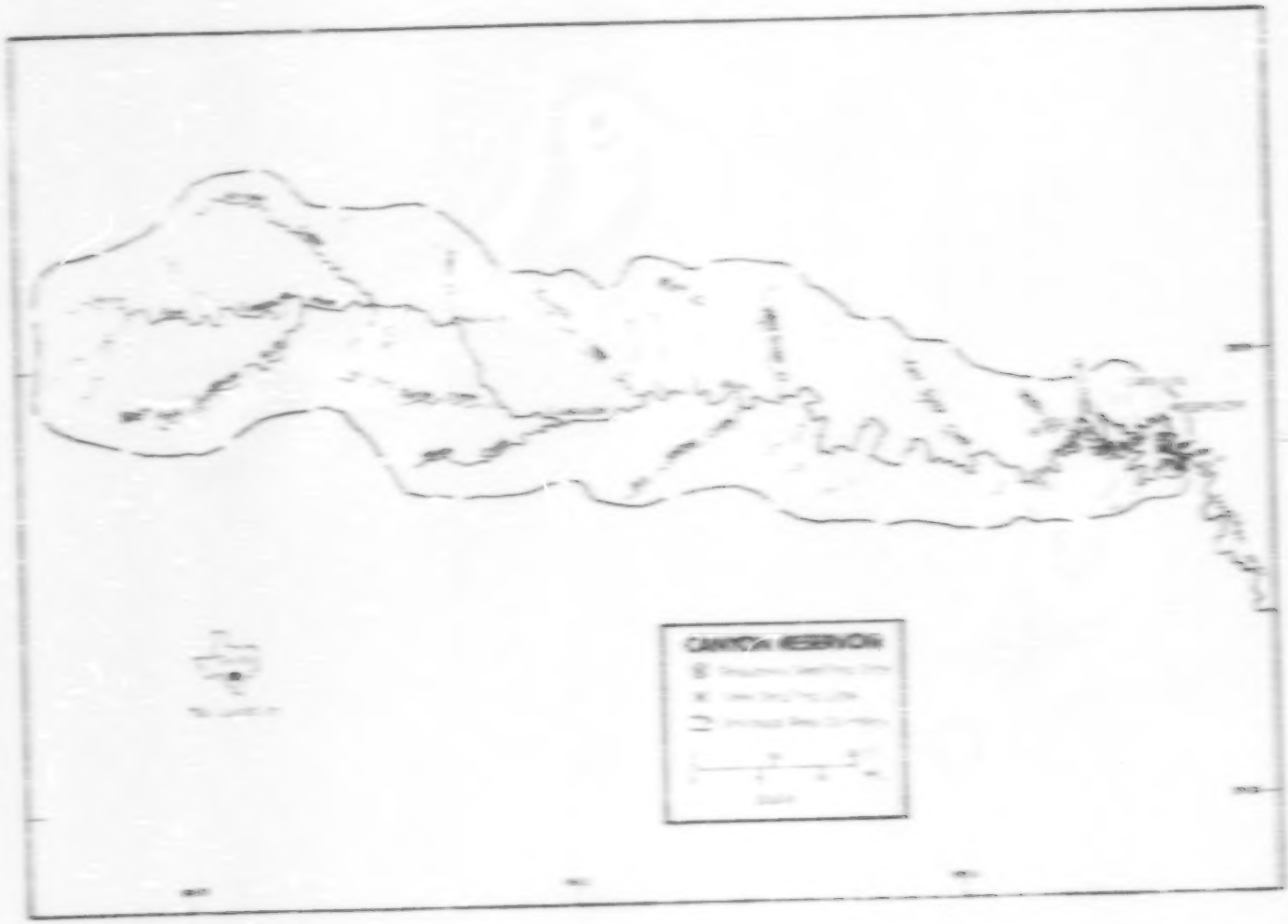
# NATIONAL EUTROPHICATION SURVEY

## STUDY RESERVOIRS

## State of Texas

| NAME | COUNTY |
|---|---|
| Amistad | Val Verde |
| Bastrop | Bastrop |
| Belton | Bell, Coryell |
| Braunig | Bexar |
| Brownwood | Brown |
| Buchanan | Burnet, Llano |
| Caddo | Harrison, Marion, TX; Caddo Parish, LA |
| Calaveras | Bexar |
| Canyon | Comal |
| Colorado City | Mitchell |
| Corpus Christi | Jim Wells, Live Oak, San Patricio |
| Diversion | Archer, Baylor |
| Eagle Mountain | Tarrant, Wise |
| Fort Phantom Hill | Jones |
| Houston | Harris |
| Kemp | Baylor |
| Lake O'The Pines | Camp, Marion, Morris, Upshur |
| Lavon | Collin |
| Lewisville (Garza-Little Elm) | Denton |
| Livingston | Polk, San Jacinto, Trinity, Walker |

| | |
|---|---|
| Lyndon B. Johnson | Burnet, Llano |
| Medina | Bandera, Medina |
| Meredith | Hutchinson, Moore, Potter |
| O. C. Fisher (San Angelo) | Tom Green |
| Palestine | Anderson, Cherokee, Henderson, Smith |
| Possum Kingdom | Palo Pinto, Stephens, Young |
| Sam Rayburn | Angelina, Jasper Nacogdoches, Sabine, San Augustine |
| Somerville | Burleson, Lee, Washington |
| E. V. Spence | Coke |
| Stamford | Haskell |
| Stillhouse Hollow | Bell |
| Tawakoni | Hunt, Rains, Van Zandt |
| Texoma | Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK |
| Travis | Burnet, Travis |
| Trinidad | Henderson |
| Twin Buttes | Tom Green |
| White River | Crosby |
| Whitney | Bosque, Hill |
| Wright Patman (Texarkana) | Bowie, Cass |



CANYON RESERVOIR

STORET NO. 4809

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Canyon Reservoir is mesotrophic; i.e., moderately supplied with nutrients and productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the reservoir. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board and there is little or no impairment of the designated beneficial uses of this water body.

Canyon Reservoir ranked first in overall trophic quality when 39 Texas reservoirs sampled in 1974 were compared using a combination of six parameters*. None of the other reservoirs had less but one had the same median total phosphorus, one had less median dissolved phosphorus, 35 had less median inorganic nitrogen, one had less mean chlorophyll *a*, and two had greater mean Secchi disc transparency.

Depression of hypolimnetic dissolved oxygen occurred at all stations in May and August, and depression with depth occurred at stations 1 and 2 in November.

B. Rate-Limiting Nutrient:

The algal assay results indicate that the primary productivity in Canyon Reservoir was phosphorus limited at the times the samples

* See Appendix A.

were collected (03/13/74 and 11/05/74). The reservoir data indicate phosphorus limitation at all sampling times.

C. Nutrient Controllability:

1. Point sources--During the sampling year, septic tanks serving shoreline dwellings were estimated to have contributed 0.4% of the total phosphorus load to Canyon Reservoir, but a shoreline survey would be needed to determine the significance of these sources. In addition, the Randolph Air Force Base Marina wastewater treatment facility discharges directly to the reservoir; however, no effluent quality data are available (Hyatt, 1976), and the phosphorus contribution of this source is not known.

The phosphorus loading of 0.15 g/m$^2$ measured during the sampling year is less than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as an oligotrophic loading (see page 14); however, the actual loading was higher to some degree because of the Randolph AFB Marina contribution. The existing reservoir water quality should persist if phosphorus inputs are kept at or below the proposed oligotrophic loading.

2. Non-point sources--The phosphorus contributions of non-point sources accounted for 99.6% of the total phosphorus load during the sampling year. The Guadalupe River contributed 77.3%, and Rebecca Creek contributed 1.0% of the total. Ungaged drainage areas were estimated to have contributed 9.9% of the total load to Canyon Reservoir.

The phosphorus export rates of the Guadalupe River and Rebecca Creek were very low (see page 13) and compare very well with the export rates of unimpacted streams elsewhere in Texas.

## II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS†

### A. Morphometry††:

1. Surface area: 33.35 kilometers².
2. Mean depth: 14.0 meters.
3. Maximum depth: >39.0 meters.
4. Volume: 471.198 x $10^6$ $m^3$.
5. Mean hydraulic retention time: 1 year (based on 1972-1976 mean outflow).

### B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

| Name | Drainage area ($km^2$)* | Mean flow ($m^3$/sec)* |
|---|---|---|
| Guadalupe River | 3,405.8 | 7.560 |
| Rebecca Creek | 28.2 | 0.146 |
| Minor tributaries & immediate drainage - | 251.3 | 1.090 |
| Totals | 3,685.8 | 8.796 |

2. Outlet -

| | | |
|---|---|---|
| Guadalupe River | 3,719.2** | 7.910 |

### C. Precipitation***:

1. Year of sampling: 85.6 centimeters.
2. Mean annual: 80.0 centimeters.

† Table of metric conversions--Appendix B.
†† At conservation pool level; Barrows, 1977.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir.
*** See Working Paper No. 175.

## III. WATER QUALITY SUMMARY

Canyon Reservoir was sampled four times during 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from four stations on the reservoir and from a number of depths at each station (see map, page vi). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the March and November visits, single 18.9-liter depth-integrated samples were composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 39.0 meters at station 1, 30.2 meters at station 2, 22.6 meters at station 3, and 15.5 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table (the August nutrient samples were not preserved properly and were not analyzed).

[illegible] SUMMARY OF [illegible] FOR [illegible] (WATER-EFFECTS) FOR DRAIN AREA [illegible]
STUDY DATE [illegible]

| PARAMETER | 1ST SAMPLING : 5/21/74 : 1215 | | | | 2ND SAMPLING : 5/22/74 : 1215 | | | | 3RD SAMPLING : 6/25/74 : 1215 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RANGE | | MEAN | MEDIAN | RANGE | | MEAN | MEDIAN | RANGE | | MEAN | MEDIAN |
| TEMP (C) | 12.0 | - 28.0 | 20.2 | 18.0 | 13.0 | - 24.2 | 22.0 | 25.1 | 15.0 | - 26.2 | 24.0 | 27.0 |
| [illegible] DEP (MG/L) | 5.8 | - 6.9 | 6.1 | 6.1 | 5.2 | - 6.2 | 6.0 | 5.9 | 6.2 | - 7.0 | 6.8 | 6.- |
| CNDCTVY (MICHOMO) | 275. | - 438. | 347. | 381. | 342. | - 544. | 346. | 385. | 335. | - 447. | 384. | 384. |
| PH (STAND UNITS) | 7.0 | - 8.3 | 6.7 | 6.2 | 5.1 | - 8.3 | 7.7 | 7.7 | 7.2 | - 8.0 | 8.0 | 6.0 |
| TOT ALK (MG/L) | 178. | - 222. | 196. | 192. | 155. | - 263. | 178. | 174. | [illegible] | | | |
| TOT P (MG/L) | 0.25 | - 0.80+ | 0.60+ | 0.567 | 0.88 | - 0.853 | 0.811 | 0.88+ | [illegible] | | | |
| [illegible] P (MG/L) | 0.48+ | - 0.611 | 0.57* | 0.57+ | 0.33* | - 0.611 | 0.58+ | 0.583 | [illegible] | | | |
| [illegible] (MG/L) | 0.38 | - 0.49 | 0.45+ | 0.44 | 0.48 | - 0.49 | 0.52 | 0.+5 | [illegible] | | | |
| [illegible] (MG/L) | 0.03 | - 0.15 | 0.0+ | 0.15 | 0.02 | - 0.06 | 0.07 | 0.04 | [illegible] | | | |
| NIT N (MG/L) | 0.26 | - 0.58 | 0.45 | 0.48 | 0.28 | - 0.46 | 0.47 | 0.38 | [illegible] | | | |
| [illegible] N (MG/L) | 0.+6 | - 0.65 | 0.5+ | 0.6+ | 0.+8 | - 0.63 | 0.57 | 0.58 | [illegible] | | | |
| TOTAL N (MG/L) | 0.56 | - 1.22 | 0.9+ | 0.75 | 0.88 | - 1.24 | 0.77 | 0.85 | [illegible] | | | |
| [illegible] N (MG/L) | 2.0 | - 3.2 | 2.9 | 3.6 | 3.5 | - 5.9 | 5.7 | 5.7 | 3.8 | - 3.6 | 3.8 | 3.6 |
| SECCHI (METERS) | 1.5 | - 4.3 | 2.9 | 2.7 | 3.6 | - 3.8 | 2.1 | 2.2 | 2.3 | - 5.5 | 3.8 | 3.7 |

B. Biological characteristics:

1. Phytoplankton -

| Sampling Date | Dominant Genera | Algal Units per ml |
|---|---|---|
| 03/13/74 | 1. Chroomonas sp. | 217 |
| | 2. Synedra sp. | 29 |
| | 3. Mallomonas sp. | 14 |
| | 4. Nitzschia sp. | 14 |
| | Other genera | 3 |
| | Total | 275 |
| 05/22/74 | 1. Chroomonas sp. | 494 |
| | 2. Coelastrum sp. | 198 |
| | 3. Cryptomonas sp. | 99 |
| | 4. Cyclotella sp. | 99 |
| | 5. Dinobryon sp. | 49 |
| | Other genera | 148 |
| | Total | 1,087 |
| 08/15/74 | 1. Cryptomonas sp. | 345 |
| | 2. Microcystis sp. | 276 |
| | 3. Chroomonas sp. | 242 |
| | 4. Tetraedron sp. | 104 |
| | 5. Navicula sp. | 69 |
| | Other genera | 310 |
| | Total | 1,346 |
| 11/05/74 | 1. Chroomonas sp. | 686 |
| | 2. Cryptomonas sp. | 172 |
| | 3. Dinobryon sp. | 103 |
| | 4. Synedra sp. | 103 |
| | 5. Chlamydomonas sp. | 69 |
| | Other genera | 102 |
| | Total | 1,235 |

F. Chlorophyll a -

| Sampling Date | Station Number | Chlorophyll a (µg/l) |
|---|---|---|
| 03/13/74 | 1 | 1.1 |
| | 2 | 0.8 |
| | 3 | 0.9 |
| | 4 | 1.2 |
| 06/22/74 | 1 | 4.4 |
| | 2 | 3.5 |
| | 3 | 7.9 |
| | 4 | 7.0 |
| 08/15/74 | 1 | 2.7 |
| | 2 | 1.0 |
| | 3 | 1.0 |
| | 4 | 3.0 |
| 11/05/74 | 1 | 2.2 |
| | 2 | 0.9 |
| | 3 | 1.1 |
| | 4 | 1.3 |

G. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. March sample -

| Spike (mg/l) | Ortho P Conc. (mg/l) | Inorganic N Conc. (mg/l) | Maximum yield (mg/l-dry wt.) |
|---|---|---|---|
| Control | <0.005 | 0.610 | 0.1 |
| 0.050 P | <0.005 | 0.610 | 7.0 |
| 0.050 P + 1.0 N | <0.005 | 1.610 | 6.4 |
| 1.0 N | <0.005 | 1.610 | 0.1 |

b. November sample -

| Spike (mg/l) | Ortho P Conc. (mg/l) | Inorganic N Conc. (mg/l) | Maximum yield (mg/l-dry wt.) |
|---|---|---|---|
| Control | 0.004 | 0.267 | 0.1 |
| 0.050 P | 0.054 | 0.267 | 6.6 |
| 0.050 P + 1.0 N | 0.054 | 1.267 | 16.4 |
| 1.0 N | 0.004 | 1.267 | 0.1 |

F. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Canyon Reservoir was low in March and November, 1974. Also, the significant increase in yields with the addition of orthophosphorus and the lack of change in yields when only nitrogen was added indicate phosphorus limitation.

The reservoir data also indicate phosphorus limitation; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 36/1 or greater at all sampling times, and phosphorus limitation would be expected.

## IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the months of April and May when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the nutrient loads, in $kg/km^2/year$, at station B-1 and multiplying by the ZZ area in $km^2$.

No known municipal or industrial waste sources impacted Canyon Reservoir during the sampling year; however, the treatment facility serving the Randolph Air Force Base Marina discharged an unknown amount of phosphorus directly to the reservoir.

* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal - None

2. Known industrial - None

B. Annual total Phosphorus Loading - Average Year:

1. Inputs -

| Source | kg P/ yr | % of total |
|---|---|---|
| a. Tributaries (non-point load) - | | |
| Guadalupe River | 3,960 | 77.3 |
| Rebecca Creek | 60 | 1.0 |
| b. Minor tributaries & immediate drainage (non-point load) - | 505 | 9.9 |
| c. Known municipal STP's - None | - | - |
| d. Septic tanks* - | 20 | 0.4 |
| e. Known industrial - None | - | - |
| f. Direct precipitation** - | 585 | 11.4 |
| Total | 5,120 | 100.0 |

2. Outputs -

Lake outlet - Guadalupe River 3,105

3. Net annual P accumulation - 2,015 kg.

* Estimate based on 65 lakeshore dwellings and two parks; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

| Source | kg N/yr | % of total |
|---|---|---|
| a. Tributaries (non-point load) - | | |
| Guadalupe River | 433,250 | 88.3 |
| Rebecca Creek | 2,099 | 0.4 |
| b. Minor tributaries & immediate drainage (non-point load) - | 18,635 | 3.8 |
| c. Known municipal STP's - None | - | - |
| d. Septic tanks* - | 836 | 0.2 |
| e. Known industrial - None | - | - |
| f. Direct precipitation** - | 36,005 | 7.3 |
| Total | 490,815 | 100.0 |

2. Outputs -

Lake outlet - Guadalupe River 174,140

3. Net annual N accumulation - 316,675 kg.

D. Non-point Nutrient Export by Subdrainage Area:

| Tributary | kg P/km²/yr | kg N/km²/yr |
|---|---|---|
| Guadalupe River | 1 | 127 |
| Rebecca Creek | 2 | 74 |

* Estimate based on 65 lakeshore dwellings and two parks; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

| | Total Phosphorus | | Total Nitrogen | |
|---|---|---|---|---|
| | Total | Accumulated | Total | Accumulated |
| grams/$m^2$/yr | 0.15 | 0.06 | 14.7 | 9.5 |

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Canyon Reservoir:

| | |
|---|---|
| "Dangerous" (eutrophic loading) | 0.72 |
| "Permissible" (oligotrophic loading) | 0.36 |

## V. LITERATURE REVIEWED

Barrows, David, 1977. Personal communication (reservoir morphometry and hydraulic retention time). Canyon Proj. Off., Fort Worth Dist., Corps of Engrs., New Braunfels, TX.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Wyatt, Linda B., 1976. Personal communication (review of preliminary report) TX Water Qual. Bd., Austin.

# VI. APPENDICES

## APPENDIX A

## LAKE RANKINGS

[illegible]

| LAKE CODE | LAKE NAME | [illegible] TOTAL * | [illegible] INCHES * | [illegible] [illegible] SEC | [illegible] CHLOR | [illegible] [illegible] | [illegible] [illegible] * |
|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LAKE [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LAKE [illegible] CITY | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | FT [illegible] [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LITTLE ELM [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LAKE OF THE PINES | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LYDIA [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LIVINGSTON LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LYNDA & JOHNSON LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LAKE [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | PALESTINE LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] [illegible] [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | SAN [illegible] [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | SAN [illegible] [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | E + SPRING [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

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[illegible] OF LAKES WITH HIGH- VALUES NUMBER OF LAKES WITH HIGH- VALUES

| LAKE CODE | LAKE NAME | [illegible] TOTAL # | [illegible] INDEX % | [illegible] MEAN SEC | [illegible] CYLIND | [illegible] [illegible] | [illegible] [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] RESERVOIR | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LAKE [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] RESERVOIR | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LAKE [illegible] CITY | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | EAGLE [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | FT [illegible] [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | GARZA LITTLE ELM [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LAKE OF THE PINES | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] & JOHNSON LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | LAKE [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | PALESTINE LAKE | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] [illegible] [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | SAN [illegible] RESERVOIR | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | SAN [illegible] RESERVOIR | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | E [illegible] SPENCE RESERVOIR | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

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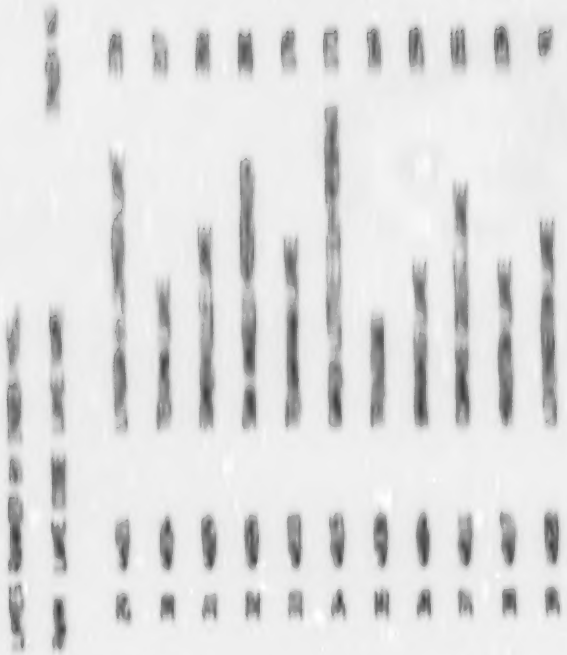

APPENDIX B

CONVERSION FACTORS

## CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x $8.107 \times 10^{-4}$ = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.206 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

# APPENDIX C

## TRIBUTARY FLOW DATA

LAKE CLUE 4MI  CANADA

TOTAL ARCHAGE AREA OF LAKE(S) 4MI  371.42

| SUB-CATCHMENT | AREA(SQ MI) | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 480441 | 371.42 | 5.87 | 6.82 | 7.67 | 8.33 | 8.34 | 8.24 | 11.51 | 8.52 | 7.19 | 7.34 | 7.46 | 7.17 | 7.91 |
| 480442 | 3485.8 | 6.88 | 7.87 | 7.19 | 8.83 | 12.91 | 9.71 | 7.22 | 4.35 | 8.41 | 5.97 | 5.78 | 5.48 | 7.56 |
| 480441 | 2+.2 | 6.19 | 8.19 | 8.11+ | 8.178 | 8.211 | 8.11+1 | 8.189 | 8.817 | 8.192 | 8.13+ | 8.695 | 8.128 | 8.396 |
| 480441 | 2+4.8 | 1.47 | 1.47 | 1.+1 | 1.22 | 1.+1 | 1.+1 | 1.+85 | 8.37 | 8.78 | 8.91 | 8.74 | 8.+1 | 1.+15 |

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 371.42  TOTAL FLOW IN = 105.25
SUM OF SUB-DRAINAGE AREAS = 371.48  TOTAL FLOW OUT = 94.89

480 MONTHLY FLOWS AND DAILY FLOWS(CMS)

| TRIBUTARY | MONTH | YEAR | MEAN FLOW | DAY | FLOW | DAY | FLOW | DAY | FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 480441 | 9 | 74 | 14,519 | 8 | 22,378 | | | | |
| | 10 | 74 | 18,477 | 8 | 78,279 | | | | |
| | 11 | 74 | 28,834 | 6 | 47,265 | | | | |
| | 12 | 74 | 13,451 | 9 | 16,461 | | | | |
| | 1 | 75 | 14,737 | 8 | 23,494 | | | | |
| | 2 | 75 | 54,368 | 7 | 14,142 | | | | |
| | 3 | 75 | 21,191 | 7 | 28,736 | | | | |
| | 4 | 75 | 16,458 | 3 | 16,537 | 21 | 19,622 | | |
| | 5 | 75 | 24,221 | 8 | 25,446 | 23 | 21,736 | | |
| | 6 | 75 | 61,469 | 9 | 46,139 | | | | |
| | 7 | 75 | 24,551 | 8 | 96,338 | | | | |
| | 8 | 75 | 15,147 | 8 | 14,171 | | | | |
| 480442 | 9 | 74 | 17,846 | 8 | 13,734 | | | | |
| | 10 | 74 | 8,203 | 8 | 6,755 | | | | |
| | 11 | 74 | 24,818 | 8 | 24,733 | | | | |
| | 12 | 74 | 14,388 | 9 | 11,379 | | | | |
| | 1 | 75 | 18,334 | 8 | 17,273 | | | | |
| | 2 | 75 | 52,852 | 7 | 65,376 | | | | |
| | 3 | 75 | 18,387 | 7 | 22,547 | | | | |
| | 4 | 75 | 15,291 | 3 | 13,451 | 21 | 11,188 | | |
| | 5 | 75 | 33,514 | 4 | 28,548 | 23 | 43,142 | | |
| | 6 | 75 | 35,376 | 9 | 31,432 | | | | |
| | 7 | 75 | 21,445 | 8 | 22,144 | | | | |
| | 8 | 75 | 15,242 | 8 | 14,171 | | | | |

# APPENDIX D

# PHYSICAL and CHEMICAL DATA

[illegible]

[illegible]
29 32 45x6 899 11 3443
[illegible]
[illegible] [illegible]

[illegible] [illegible]
3 [illegible] [illegible]

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
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| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

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[illegible]

[illegible]

| DATE | TIME | DEPTH | [illegible] | [illegible] | [illegible] |
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| [illegible] | OF | | | & | [illegible] |
| TO | DAY | FEET | [illegible] | [illegible] | [illegible] |
| [illegible] | 11 | 20 | [illegible] | [illegible] | |
| | 11 | 70 | [illegible] | [illegible] | |
| | [illegible] | 20 | [illegible] | [illegible] | |
| | 11 | 20 | [illegible] | [illegible] | |
| | 11 | 70 | [illegible] | [illegible] | |
| | [illegible] | 25 | [illegible] | [illegible] | |
| [illegible] | 09 | 95 | [illegible] | [illegible] | |
| | 09 | 95 | [illegible] | [illegible] | |
| | 09 | 95 | [illegible] | [illegible] | |
| | 09 | 95 | [illegible] | [illegible] | |
| | 09 | 95 | [illegible] | [illegible] | |
| [illegible] | 10 | 45 | [illegible] | [illegible] | |
| | 10 | 45 | [illegible] | | [illegible] |
| | 10 | 45 | [illegible] | | [illegible] |
| [illegible] | 10 | 50 | [illegible] | [illegible] | |
| | 10 | 50 | [illegible] | | [illegible] |
| | 10 | 50 | [illegible] | [illegible] | |
| | 10 | 50 | [illegible] | | [illegible] |
| | 10 | 50 | [illegible] | [illegible] | |
| | 10 | 50 | [illegible] | [illegible] | |
| | 10 | 50 | [illegible] | [illegible] | |
| | 10 | 50 | [illegible] | [illegible] | |

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29 53 28.8 098 17 [illegible]
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| DATE (YYMMDD) TO | TIME OF DAY | DEPTH FEET | [illegible] | 32217 CHLRPHYL A UG/L | 00631 INCT LT REMOVAL PERCENT |
|---|---|---|---|---|---|
| 74[illegible]13 | 12 | 00 | 0000 | [illegible] | 1.2 | |
| | 12 | 00 | 0005 | [illegible] | | |
| | 12 | 00 | 0010 | [illegible] | | |
| | 12 | 00 | 0020 | [illegible] | | |
| | 12 | 00 | 0030 | [illegible] | | |
| | 12 | 00 | 0050 | [illegible] | | |
| 74/05/23 | 10 | 15 | 0000 | [illegible] | 7.0 | |
| | 10 | 15 | 0005 | [illegible] | | |
| | 10 | 15 | 0010 | [illegible] | | |
| | 10 | 15 | 0025 | [illegible] | | |
| | 10 | 15 | 0035 | [illegible] | | |
| | 10 | 15 | 0050 | [illegible] | | |
| 74/08/15 | 11 | 20 | 0000 | | 3.0 | |
| | 11 | 20 | 0002 | | | 50.0 |
| | 11 | 20 | 0020 | | | 1.0 |
| 74/10/05 | 11 | 20 | 0000 | [illegible] | 1.3 | |
| | 11 | 20 | 0005 | [illegible] | | |
| | 11 | 20 | 0010 | [illegible] | | |
| | 11 | 20 | 0025 | [illegible] | | |
| | 11 | 20 | 0030 | [illegible] | | |

# APPENDIX E

# TRIBUTARY DATA

[illegible]

| DATE | TIME | DEPTH | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|
| FROM | OF | BOTTOM | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| TO | DAY | FEET | MG/L | MG/L | MG/L | MG/L * | MG/L * |
| 74/12/02 | 11 | 05 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 74/12/09 | 09 | 45 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 74/11/08 | 10 | 45 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 74/12/04 | 12 | 00 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/01/04 | 00 | 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/02/07 | 00 | 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/03/07 | 11 | 00 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/04/21 | 09 | 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/04/21 | 13 | 05 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/05/08 | 09 | 35 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/05/23 | 09 | 15 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/06/04 | 09 | 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/07/08 | 09 | 00 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 75/08/06 | 09 | 15 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

* VALUE KNOWN TO BE LESS THAN INDICATED

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| [illegible] | [illegible] | FEET | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
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| DATE | TIME | DEPTH | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
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